Amazon Forest Structure Generates Diurnal and Seasonal Variability in Light Utilization

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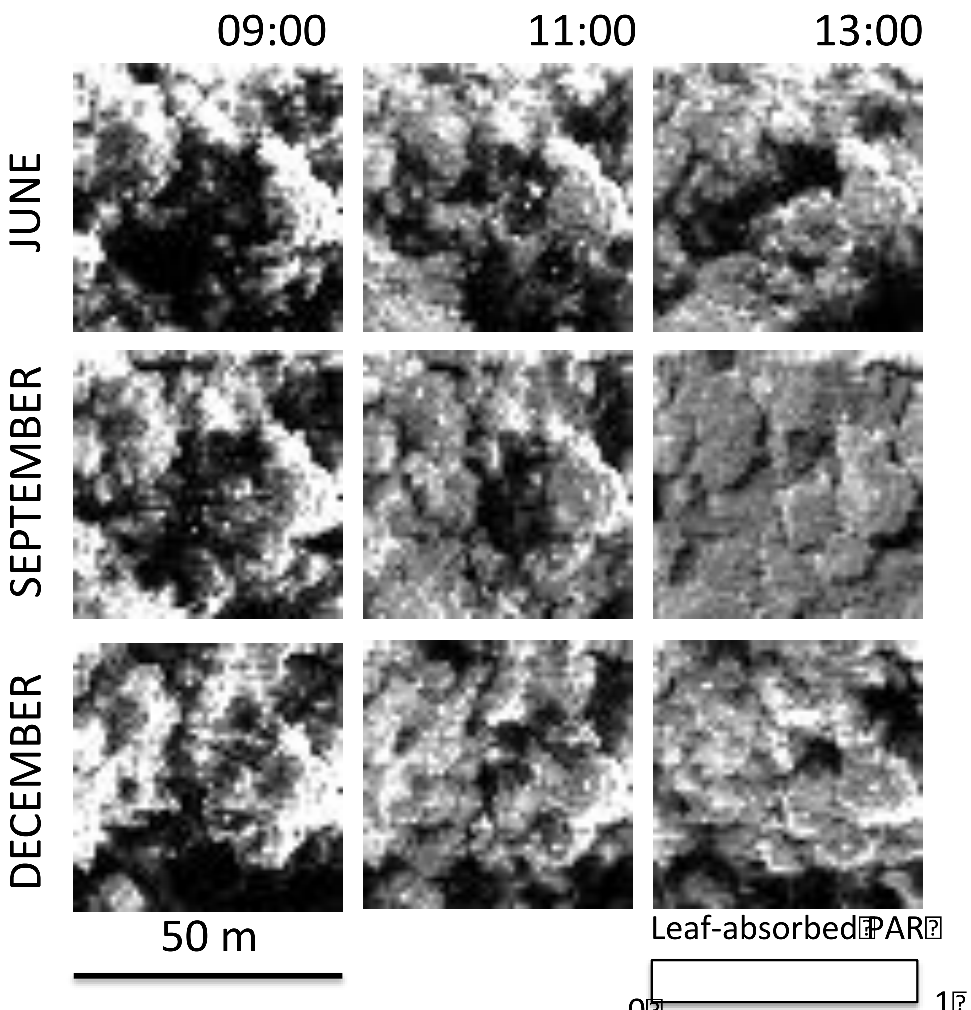
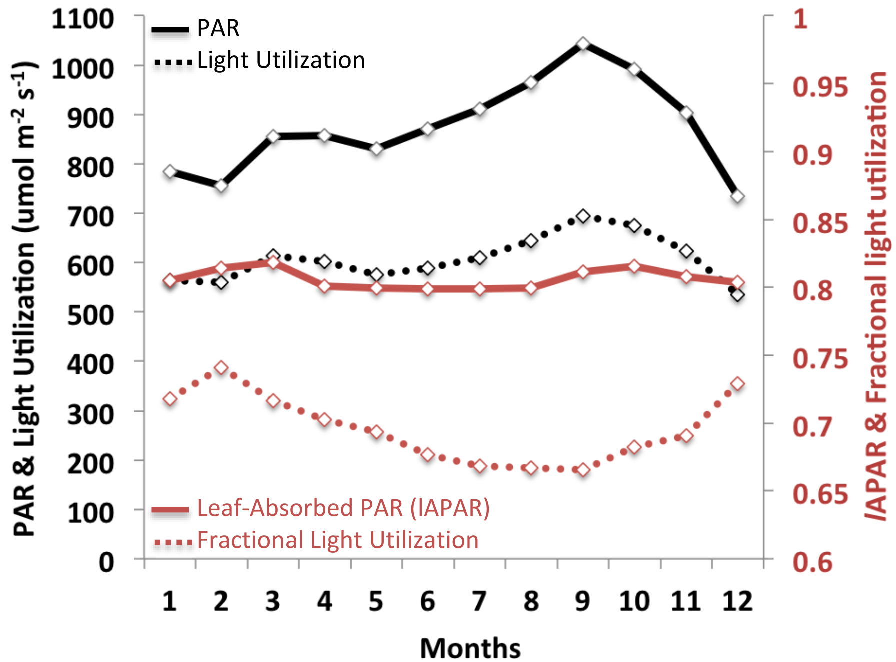
- Tropical forest 3D structure generates a diversity of light environments.
- Diurnal and seasonal changes in illumination geometry and the fraction of diffuse radiation alters the distribution of photosynthetically active radiation (PAR) across canopy leaf area.





Key result: Shadowing and light saturation effects at the leaf level generate seasonality in light utilization, the amount of leaf-absorbed PAR available for photosynthesis, without changes in canopy composition from phenology.

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References:
1. Morton DC, Rubio J, Cook BD, Gastellu-Etchegorry J-P, Longo M, Choi H, Hunter MO, Keller MM. Amazon forest structure generates diurnal and seasonal variability in light utilization*. **Biogeosciences Discussion***, in press.
2. Morton DC, Nagol J, Carabajal C, Rosette J, Palace M, Cook BD, Vermote E, Harding D, North P. Reply to Saleska et al. ***Nature***, in press.
3. Morton DC, Nagol J, Carabajal C, Rosette J, Palace M, Cook BD, Vermote E, Harding D, North P. Amazon forests maintain consistent canopy structure and reflectance during the dry season. ***Nature***, doi:10.1038/nature13006 (05 February 2014).

Data Sources: This study combined airborne lidar data (http://mapas.cnpm.embrapa.br/paisagenssustentaveis/) and *in situ* measurements of leaf area, leaf reflectance, incident photosynthetically active radiation (PAR), and Aeronet aerosol data to evaluate the influence of changing illumination geometry on Amazon forest productivity. Remote sensing and field information was used to generate a 3D forest scene in the Discrete Anisotropic Radiative Transfer (DART) model (http://www.cesbio.ups-tlse.fr/us/dart.html). DART separately tracked light interactions with leaves, woody branches and stems, and the ground surface. Model simulations for five hours per day and one day per month were used to quantify the impact of changing sun angle, cloud cover, and aerosol loading on the distribution of light absorption at the leaf level.

Technical Description of Figures:
Figure 1. The nine figure panels illustrate the influence of changing solar illumination and the fraction of direct/diffuse radiation on the distribution of leaf-level light absorption for the Amazon forest scene. Shades from black to white indicate the leaf absorbed PAR for simulations in three months at 09:00, 11:00, and 13:00. Shadowing and illumination changes are clearly visible, with most uniform distribution of incident light for the September 13:00 simulation with near-nadir solar illumination.
Figure 2. Monthly summary of DART model simulations. PAR (solid black) and modeled light utilization (dashed black), based on a weighted average of hourly DART simulations. Modeled monthly values of leaf-absorbed PAR (lAPAR, solid red) and fractional light utilization (dashed red) are plotted on the right-hand axis.

Scientific Significance: Seasonal dynamics of tropical forest productivity remain an important source of uncertainty in assessments of the land carbon sink. Previous studies have suggested that Amazon forests may respond to increases in light availability during the dry season with large increases in canopy leaf area or leaf reflectance. Morton et al. (2014) used lidar data from NASA's ICESat GLAS instrument and MODIS passive optical data to test these hypotheses, but found no consistent evidence for large net changes in canopy leaf area or reflectance. Instead, that paper hypothesized that seasonal changes in illumination could generate the observed patterns of forest productivity. This study (Morton et al, in press *Biogeosciences Discussion*) confirms the potential for canopy structure and illumination geometry to alter the seasonal availability of light for canopy photosynthesis without changes in canopy composition. These results point to the need for more consideration of forest structure in ecosystem models to account for the impact of changing illumination geometry on tropical forest productivity.

Relevance for Current & Future Missions: The findings have direct bearing on studies of tropical forest productivity from satellite measurements (e.g., OCO-2 xCO_2 and solar-induced fluorescence, SIF), based on the distribution of sunlit and shaded canopy elements, and a range of carbon cycle and ecosystem research efforts funded under NASA Earth Science Programs.